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MOVABLE DAMS

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ON THE ADAPTATION OF MOVABLE DAMS TO THE OHIO AND OTHER RIVERS OF THE UNITED STATES AS PRACTICED BY THE UNITED STATES CORPS OF ENGINEERS.

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DATA.

Reports of Cols. Craighill, Merrill and their assistants to the Chief of Engineers; of various Boards of Engineers detailed to examine and report upon said works. Personal inspection of the work at Davis Island, and an extensive correspondence. Due acknowledgement is herein made by references embodied in the text.

Introduction.

The problem of the improvement of the Ohio River and its tributaries has engaged the attention of the Civil and Military Engineers of the United States for many years, but it is not proposed to detail the history of these projects further than to show the condition of the science at the time when the present works were undertaken and the recent modifications, which have rendered the application of the "French Dams" of Mr. Chanoine possible on so large a scale.

Among the early projects was that of the improvement by dams and dikes begun on the Ohio in 1836, and which proved so successful that it was subsequently extended.

Another plan was suggested by Chas. Ellet, Jr., C. E., in 1850, which consisted of large storage reservoirs in the mountains of adjacent States from which it was proposed to keep up the required stage of water, but it was never put in operation. More recently it was proposed to improve by combining (1) the contraction of the width of the channel by building lateral dams, with (2) the reduction of the slope of the river bed by bottom

dams, and (3) the retardation of the flow by the use of removable obstructions.

Having maturely considered these various projects, a Board of United States Engineers, composed of General G. Weitzel (deceased) and Col. Wm. Merrill, was appointed to "report upon the applicability of Hydraulic Gates and Dams in the Ohio River."

Their exhaustive report was made to the Chief of Engineers *January* 31*st*, 1874, and contains a description of all the improvements of this character then known to exist. It contains some extracts from the descriptions of MM. Hagen and Becker, of the existing movable dams on the continent of Europe and especially in France. In their introduction the Board say,* in reference to the use of the system on the Ohio: "The average width of a coal fleet is 125 ft. The least width of chute that can now, in advance of experience, be assumed as necessary, is two hundred (200) feet. The first question, therefore, is: Can a gate be constructed than can be made to close or open this passage at will?

"The following extracts from Hagen and Becker will show what has thus far been done in this country and Europe. . . . . Hagen remarks in his preface, 'No one of the different plans that have been suggested seems yet to furnish a full solution of the problem,' and he adds:

"'A complete solution . . . seems to require that the pressure of the water, whether standing or flowing, should furnish the power by which the dam is erected or removed. Or, again, the construction must be such that, notwithstanding the requisite solidity of the structure, it can be managed with a slight power, for which only a few men and a short time are required.'"

Then follows a description of all of the methods which the Board could obtain, that had been used up to that time for the management of hydraulic gates or movable dams. "The following are the methods thus far described: (1) the Bear Trap; (2) the wicket used on the Riom; (3) Thénard shutters; (4) Thénard shutters modified by Fouracres; (5) Poirée needle-dam; (6) Poirée and Thénard combined; (7) Chanoine wickets; (8) Des-

* Ex. Doc. No. 78, H. of Rep., 43d Cong., 2d Session, page 3.

fontaines wickets; (9) modified Poirée needle-dam; (10) Cuvinot drum wickets; (11) Krantz wickets, with ponton; (12) Carro gates; (13) Girard shutters."

Since the preparation of the reports above mentioned, numerous other solutions have been presented for the general problem as stated by Mr. Hagen, and many modifications have been made in detail, by which the application of existing methods are made more efficient and far reaching.

History.

Under this head I can merely outline, in the most general manner, the steps taken to apply the system as now used in France to American rivers.

Prior to August, 1874, Col. Wm. E. Merrill, United States Engineer, was in charge of the improvement of the rivers of the Ohio basin, and to him more than to any other person is due the credit of examining, testing and applying this system. He has reviewed the subject completely, translating all the available foreign literature relating to it, and has made numerous special reports and recommendations thereon, both separately and in connection with other officers. As early as April 16th, 1872, the then Chief of Engineers, General A. A. Humphreys, issued a Special Order No. 44, constituting Gen. G. Weitzel and Col. Wm. E. Merrill a Board "to examine and report upon the plan of Mr. F. R. Brunot for movable hydraulic gates for chutes and locks, its applicability to the improvement of the Ohio and other rivers, and an estimate of the cost of construction." To this duty was subsequently (May 1st, 1872) added the general consideration of the whole subject of hydraulic gates. A preliminary report was made January 14th, 1873, recommending an appropriation of $40,000 to make a test on the Monongahela, but without reference to any particular plan. A full report of all the then known devices was made on January 31st, 1874, in which the members of the Board say "they are now prepared to submit a plan which they feel confident will fully meet the necessities of the case." What this plan was is best given in Col. Merrill's Report, N. 1 of September 1st, 1874,* where he says: "After long study I

* Report of Chief of Engineers, 1874, p. 406.

have come to the conclusion that the best method of improving the Ohio, at least in the upper part of its course, is to follow the plans that have been so successful on the Seine, Yonne, Marne, Meuse and other French rivers. . . . The system that meets with most favor in France is that known from its inventor as the Chanoine." Before proceeding to describe this system it will be necessary to state in this connection that, pending the efforts of Col. Merrill to remove the legal obstructions to the erection of movable dams on the Ohio, several such dams were begun on the Great Kanawha by Col. Wm. P. Craighill, who was placed in charge of the improvements of that and other rivers in August, 1874. In recommending the adoption of the system in this district Col. Craighill, in a letter to the Chief of Engineers, dated April 30th, 1875, says: "The adoption of movable dams seems the best expedient available, as the system is used, for instance, on the Seine, and as described in the report of Majors Weitzel and Merrill. These will furnish an unobstructed navigation during . . . not less than six months in each year. The system has not been fairly tested in this country, but its long successful use in France would seem to supply the deficiency and justify its adoption under favorable conditions, such as are found on the Kanawha. . . . I incline decidedly to the use of the Chanoine movable dam at this locality (near Brownstown*) and at all points below and perhaps some above it. . . . Were I free to proceed, I should apply the available appropriation to the construction of a lock with movable dam near Brownstown . . making the lock 300 ft. long in the clear, 50 ft. wide, with a lift of about 8 ft., the dams to have a navigation-pass of 250 or 300 ft, arranged according to the Chanoine plan. . . The cost would be $286,000."

The project having been approved, contracts were made for building the lock, near Brownstown, August 20th, 1875, and for the dam, abutment, pier and floor of a navigation-pass adjoining, on March 28th, 1876. (The contract for lock No. 4, near Cabin Creek Shoal, was made October 15th, 1875.)

At the site of lock No. 5 the width of the river at low water is 575 ft.; between the tops of the banks, which are 45 to 50 ft. high,

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* Lock and Dam, No. 5. Report of 1875, Part II, pp. 90, et seq.

it is 800 ft. The average depth to river bed, in low water, is 4 ft. The navigable pass is 250 ft. long, and the weir is 265.42 ft. Dredging for the pass was commenced September 19th, 1877; the erection of the cofferdam September 26th. The lock of No. 5 was completed in August, 1878. The contractor for the dam abandoned his work in October of 1878, and it was continued by day's labor, under the Government. The pass of No. 5 was completed, except placing the wickets, on August 14th, and that of No. 4 on August 16th, 1879. The weirs at both sites were finished, ready to receive the wickets, on November 1st, 1879.

In his annual report for 1880, Colonel Craighill, says: * "At the date of this report (July 22d, 1880) locks and dams 4 and 5 are essentially finished, according to the Chanoine system, and usable." (The pictorial illustrations accompanying this report, probably made from photographs, show the dam up and a steamer passing through the lock, also various stages of the work during construction.)

In the report for 1881, Capt. E. H. Ruffner, U. S. E., says † of lock and dam No. 4: ‡ "This work was practically completed on the 3d of July, 1880, when the first lockage was made. § Since then the dam has been lowered and put up three times. It has been up a total of 146½ days to this date (June 1st, 1881)." . . . .

"The work on lock and dam No. 5 was completed so that the first lockage was made July 16th, 1880. Since that date it has been raised and lowered three times. It has been up a total of 122¾ days."

Thus it will be seen that, pending the consideration of the application of the system to so large a river as the Ohio, these two Chanoine movable dams, known as Nos. 4 and 5, were actually completed on the Great Kanawha, near Brownstown, in July, 1880, and were therefore the first in the United States.

The Davis Island Dam on the Ohio.

It having finally been decided to test the method on the Ohio,

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* P. 682, Part I, Report of Chief of Engineers, 1880.

† P. 913, Part I, Report of Chief of Engineers, 1881.

‡ Length of pass, 248 ft.; of weir, 210 ft.; pier, 10 ft.; of dam, 468 ft.

§ It was, therefore, the first Chanoine dam in the United States.

authority was given to begin work at the site of Davis' Island, $5\frac{1}{2}$ miles below Pittsburgh, on July 24th, 1878, and in conformity therewith work was commenced on the 19th of August following. After numerous modifications the following dimensions were adopted as being those best adapted to fulfill the requirements of an extensive commerce:

Dimensions of lock chamber, in the clear, . .	600x110 ft.
Length of navigable pass (sill on river bed), . . .	559 "
" " weir No. 1 (sill 1 ft. above river bed), . .	224 "
" " " No. 2 (" 2 ft. " " "), . .	224 "
" " " No. 3 (" 3 ft. " " "), . .	216 "
Total length on main channel, ...	1223 "
" " with piers, ...	1260 "
Permanent dam across back channel, ...	456 "

Number of wickets (12′ $1\frac{1}{2}$″ x 3′ 9″) in navigable pass, .	139
" " " (11′ $1\frac{1}{2}$″ x 3′ 9″) on weir No. 1, . .	56
" " " (10′ $1\frac{1}{2}$″ x 3′ 9″) " " No. 2, . .	56
" " " (9′ $1\frac{1}{2}$″ x 3′ 9″) " " No. 3, . .	54
Total number of wickets, etc., ...	305
Additional wickets required for use in the lock, .	27

The wickets are spaced 4 ft. apart between centers, leaving 3 inches clearance. The first wicket was erected in presence of the Ohio River Commission, September 27th, 1881. The last of the pass wickets was put in October 29th, at 10 A.M. In the official report of the year ending July 1st, 1883, Col. Merrill says the weirs 1, 2 and 3 are completed, including the erection of a service bridge, from which the wickets of these weirs are to be handled.

At my last visit to this work I met Col. Merrill at the lock, and through his courtesy I was enabled to examine the details of the work and the drawings. I found there were 4 ft. of water on the sill of the dam, which was down, and that large "tows" had no difficulty in stemming the current, which at that place was quite rapid. The improvement is almost completed, as there only remains to be put in place the lock gates, with the turbines

and other machinery for operating them, which it is expected will be done next Spring.

The cost of the work it is difficult to obtain.

The estimate of the engineer in charge for 1879 was	$200,000
The same amount was asked for the year 1880 .	200,000
For 1881, ...	200,000
For 1882, ...	200,000
The reported expenditures for 1883 were, . .	208,594
The detailed estimate to complete the work, 1884–85, is	110,400
	$1,119,000

The amount of the unexpended balances is not known.

Lock No. 6 (for Movable Dam).

(On the Kanawha, 4 miles below Charleston and 54 above the mouth of the river.)

The improved Chanoine dam on the Kanawha was found to be so successful that another one, known as Dam No. 6, 558 ft. long,* was practically begun in the Spring of 1881 and nearly finished by July, 1883. It was estimated that it would be completed in three or four months thereafter. Dam No. 7† will also be made movable. Its site is 10 miles below No. 6, which is 13.2 below No. 5.

The Chanoine System of Movable Dams.

As this system has been selected by competent engineers after mature deliberation; has been put in operation on the Kanawha and Ohio Rivers, and has been found successful, and as its further introduction is only a question of time, I hope I will not be trenching too greatly upon your patience if I give a brief description of the system and the modifications which render it so successful.

The elements of the *barrage mobile* or movable dam are a wicket, a horse, a prop, a floor to support these several parts, and the devices for manœuvering them.

The wicket is merely a strong rectangular shield or panel, of variable dimensions, hinged to an axis placed at a height of one-

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* 248 ft. of pass and 310 of weir. Lift of lock, 8$\frac{3}{4}$ ft.

† 520 ft. long—248 ft. pass, 260 ft. weir, 12 ft. pier; 8$\frac{1}{4}$ ft. lift.

third the length of the wicket from the bottom, for weirs, and of seven-twelfths the height for the passes.

The part of the wicket below this axis is called the *breech*, that above the *chase*.

To the same axis is hinged the head of an iron frame, called the *horse;* the feet of which are hinged to the floor of the pass, just behind the sill, so that when the wicket is raised its plane will be inclined down stream at an angle of 20°, while the horse will be inclined up stream at an angle of 5° from the vertical.

The *prop* makes an angle with the horizon of 37°. It is hinged at its upper end to the axis of oscillation of the wicket and at the foot it is supported by a cast iron block, called a *hurter*, which is rigidly bolted to the floor of the dam. The wickets are thrown down by means of a long iron bar extending across the dam, having projecting lugs, called *catches*, so spaced, that, as the bar is moved by means of a rack and pinion attached to the abutment, the feet of the props are "tripped" in succession, and, being drawn into a lateral groove, slide to the rear and allow the wickets to fall abruptly upon the floor of the pass. Counter-catches on this tripper-bar, equally spaced, at intervals corresponding to those between the centers of the wickets, prevent the props from being thrown down by floating bodies when the dam is up. The wickets are raised by means of a crab, placed in a manœuvering boat or on a service bridge, which is so constructed of iron trestles as to be folded down below the level of the sill after the dam is thrown, and thus offer no obstruction to navigation or to drift.

From this description it will be seen that the success of this system of movable dams for river improvements depends upon the co-operation of all the parts of the mechanism, and the application of the power at the proper times. The principal elements in these two factors are human vigilance and fidelity combined with mechanical possibilities.

The practical operation is best shown by quoting the results of experience, as given by Capt. Ruffner, with Dams Nos. 4 and 5 on the Kanawha, during the season of 1880–81.* In regard to

* Report of Chief of Engineers, 1881, p. 914.

Manœuvering the Dams,

he says: "Although considerable trouble has been had, nothing serious has occurred, and the working on the whole has been as satisfactory as could be expected. The difficulties decrease with experience . . . As was to be anticipated, the tripping-bars have been the principal cause of trouble, and the desirability of getting rid of them, if possible, is clearly proved. They become foul from stone, gravel, sticks and cinders (the last is quite troublesome), that get on and *under* them and *in* the gearing wells. This is particularly the case when the dams are down, and a good deal of time and hard disagreeable work are always required to get the bars in working order before the wickets can be righted. Besides this they frequently fail to trip (the tripper passing the prop, as it will when the latter is not well down in its seat in the hurter), and the wicket is left standing to be pulled down from below, a slow and difficult operation. It is true that a careful examination of every prop by the diver in raising does away with the most of this difficulty, but not entirely, for a prop will sometimes be overlooked and cause the loss of precious time when the dam is thrown. It is believed that the adoption of the Pasqueau hurters* at both 4 and 5 is advisable, and it is respectfully recommended that steps be taken to give them a trial by placing them on one bar-section at one of the dams as soon as practicable."† . . .

Mr. A. M. Scott, Assistant Engineer, in reporting on the operation of the tripping-bar at No. 4 to July, 1883, is even more emphatic and specific. He says:‡ "This dam has been entirely up 143 days during the year. It was thrown down June 29th, 1882. It was put up July 10th in 10 hours and 15 minutes. Some

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* U. S. Patent No. 225533. Application filed, January 19th, 1880. Issued, March 16th, 1880, to Alfred Pasqueau, of Lyons, Department of the Rhone, France.

† As early as Aug. 9th, 1880, the Engineer in Charge of the Ohio River improvements, suggested the appointment of a Board of Engineers to consider the advisability of introducing the Pasqueau hurter and a straddling traveler for the Davis Island dams, both of which modifications were approved. See Supplement to this paper by Col. Wm. E. Merrill, published in Proceedings of Engineers' Club.

‡ Report of Mr. A. M. Scott, Assistant Engineer to Col. Wm. P. Craighill, U. S. Engineer on Dam No. 4, Great Kanawha River, West Virginia (Report of Chief of Engineers, 1883, Vol. I, p. 711.)

delay was occasioned by a large rock found wedged under the tripping-bar. It was thrown again on the 13th in two hours, everything working right. Began to raise July 19th at 9.30 A.M.; finished on 22d at 5.15 P.M. Delay caused by lock section of tripping-bar being off the guides and a broken bed-plate in the gearing-wells. Dam thrown again for a rise August 20th* at 7.30 P.M.; all down at 10.30 P.M. Began to raise August 14th; finished 3 P.M. of 15th. Delay caused by broken pinion in lock gearing wells. Dam lowered September 1st in 1 hour and 45 minutes. Put up on 7th in 7 hours and 30 minutes.

The dam was lowered for a rise September 11th between 12 30 and 3.50 P.M. Three pass wickets failed to trip and were hooked down from below. The dam was raised September 25th and 26th in $9\frac{1}{4}$ hours.

It was again lowered for the Winter (a good deal of ice moving), December 8th and 9th; finished 5.10 P.M. The tripping-bar refused to work and the twenty-eight wickets were lowered with winch and hook. May 7th (1883) began to raise the dam. All up on the 21st. The pinions in both gearing wells were found broken. The repairs necessitated the removal and replacement of the shafts, bottom rollers, guides, etc., a troublesome and disagreeable job. The whole force and an extra man were at work most of the time, from the 9th to the 20th, in cleaning out the gearing wells, replacing the shafts and pinions, in short, in getting the tripping-bars in working order.

"The dam was lowered June 12th and 13th and raised again on the 18th. In lowering, three pass wickets failed to trip and were hooked down. The lowering of the bridge was much delayed by green brush and trees that had been cut and thrown in the river above. In raising $5\frac{1}{2}$ hours were taken in getting the pier tripper into gear, it having been pushed out too far after lowering."

From this description of operations during the fiscal year 1882–'83, it appears that the dam was lowered six and raised seven times. Total number of manœuvers 13. The least time required to raise the dam was 7 hours and 30 minutes, and to throw it down 1 hour and 45 minutes. Only twice in the raising

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* Probably intended for 12th.

and thrice in the lowering does it appear to have worked without accident or unusual delays. On the other eight occasions detentions were caused either by the wedging of the tripper-bar, or from the catches failing, pinions breaking, rack getting out of gear, or other defect in the mechanism.

These failures are doubtless largely due to the increased length of the passes and heights of the wickets, which have been found necessary to accommodate the large "tows" of our western rivers. The longest foreign pass, operated by Chanoine dams with tripping-bar, that I have been able to find recorded, is that at Melun, where the pass is 213.53 ft., with 50 wickets 9.51 ft. high. The longest *weir* is that at Le Coudray dam 229.93 ft., with 50 wickets 6.23 ft. high. This gives but 28.65 sq. ft. of surface on each of the 50 *weir* wickets, and 40.61 sq. ft. on each of the 50 pass wickets, exposed to pressure when the pool is full. At dam No. 5 on the Kanawha there are 62 pass wickets ($13' \, 9'' \times 3' \, 8''$) giving a pressure due to $50\frac{5}{12}$ sq. ft. on each of the props of the wickets, which is 25 per cent. more than that allowed in France. This pass was originally divided into two sections and operated by two trip-bars, one "about 142 ft. long," manœuvered from the lock wall, the other "about 120 ft. long" from the pier.

It is therefore evident that a system based upon this mechanism has but a limited application and is not well adapted to the requirements of *American* inland navigation, but the invention of the Pasqueau hurter was fortunately made just in time to be of great service, and its adoption by government engineers, already alluded to, has saved the system from numerous embarrassments and possible failure.

Concerning the use of the Pasqueau hurters at Lock and Dam No. 5, on the Kanawha,* Capt. Ruffner says, "it (the dam) was up from July 1st to Sept. 18th, 1881, when it was lowered for a rise." . . . (It was lowered in $2\frac{3}{4}$ hours by 7 men.) . . . "Preparations were made to raise Sept. 23d, 1881, when it was found that the lock section of the tripping-bar lacked about four inches of being back to place," etc. (The bar was broken in trying to force it

* Extract from Appendix G., Report of Capt. E. H. Ruffner to Col. Craighill—Report Chief of Engineers, p. 922, Vol. I., 1882.

out while off the guides). "Authority having already been given to try the Pasqueau hurters on a section of either dam 4 or 5, the broken bar was entirely removed, and measures taken to place the improved hurters on the whole section." . . . Three of the new hurters were placed last Fall. There are now 14 of the new hurters in. About two weeks more of comparatively low, clear water will be required to place the remaining 18." . . . "The Pasqueau hurters are adapted to the old *slides*." . . . "It is hoped that the new hurters will turn out a decided improvement"*

Mr. A. M. Scott, Assistant Engineer, says:† "The dam has been up 111 days during the year (1882–83). The placing of the Pasqueau hurters on the lock section was completed Aug. 12th (1882), and the dam was entirely up on the 15th. . . . In lowering (Aug. 31st), the tripping-bar on the pier section refused to work, and the Pasqueau section was thrown first—the 34 wickets being lowered in 1 hour and 35 minutes (they have since been thrown, as reported below, in considerably less time). After this, the 28 pier-section wickets were lowered by winch and hook, pulling ahead at top from bridge, and tripping from boat below; whole time taken in lowering, 3 hours and 55 minutes."

(Thus the pass wickets, in deeper water, operated by the Pasqueau hurter were thrown in 2.8 minutes each, whilst the weir wickets, less than half the size, required, when thrown by hand, without use of tripping-bar, 8.4 minutes each.)

On Sept. 11th, an exceptionally heavy rain-fall required the lowering of the dam. "The order to begin was given by telephone at 9.40 A.M., and the lowering commenced at once on the lock (Pasqueau) section. These 34 wickets were thrown down withwithout any trouble in 1 hour and 20 minutes. The water was rising so fast that with the 34 wickets down, it was nearly up to the top of those standing, and the "back lash" and "roll" below the dam were so bad that it was impracticable to *pull* the pier wickets down (the tripping-bar was out of order). The same was

* The lock section of the tripping-bar, and 50 feet of the weir section were replaced by 46 Pasqueau hurters. The dam was up 121 days during the year.

† In the Report Chief of Eng., Part I, p. 712, 1883.

true of the wickets of the weir (they were all on the swing), and it was decided to lower the bridges, and leave the 28 pass and all the weir wickets up. The bridges went down all right and were out of the way at 1.30 P.M. The water reached its height (about 19½ feet above low water at lock) on the 13th, and fell so that the 28 pass wickets were lowered on the 16th. *No damage was done to either of the pass or weir wickets by the rise.* As stated, the 34 Pasqueau arranged wickets were thrown from the bridge in 80 minutes. (They have since been thrown in less time. In November, 23 of them were lowered, after the head had run down to about two feet, however, in 20 minutes.) . . . *It is apparent that even under these extraordinary circumstances, with Pasqueau hurters throughout, on both pass and weir, the whole dam could have been safely lowered after* 9.40, *with time to spare.* . . . The year's experience has demonstrated the successful working of the Pasqueau hurters and their decided superiority, particularly as applied to this river, over the tripping-bars. In fact, the advisability of avoiding the tripping-bars in future construction, and of getting rid of those already in use as soon as practicable, is considered well established."

Capt. F. A. Mahan, U. S. Corps of Engineers, who was for some years the principal assistant to Col. Merrill, in charge of the Davis Island Dam, has written a supplement to River Improvements in his father's work on Civil Engineering, in which he says (p. 519, edition 1884): "The trip-bar is the weakest feature of the Chanoine dam. The machinery to move it is more or less complicated, it is liable to get out of order, and if, for any reason, one wicket should refuse to go down, the movement of the bar is stopped, and the rest of the dam has to remain standing. By an arrangement of the hurter lately made, the trip-bar is done away with altogether. The hurter has two steps, the higher, which is the prop-seat, is made with a sort of pocket for the end of the prop to rest in, the lower has its down-stream face vertical, and making a very acute angle with the axis of the passage. The wicket is raised as in the ordinary system. The breech chain is pulled in until the prop falls into its seat. . . . The panel is righted by letting out the breech-chain slowly until the sill is touched.

"To lower the wicket it is first brought to the swing by raising

the breech. The motion is continued until the head of the horse is pulled up stream dragging the prop, which then falls down the second step, and is thus left without support. The inclined face of this second step directs the prop towards the passage of the hurter. The weight of the system carries it down, and the chain being paid out slowly prevents it from falling to the bottom with a shock. By means of this device each wicket is entirely isolated and independent. One of them failing to act will not cause any interference with the other, and even in the event of any difficulty, the absence of counter catches makes it easy to knock down a prop from a skiff below the dam. A further advantage is that the navigable pass can be made of any width desired, which was not the case with the old trip-bar, because there the width of the pass could not exceed twice the length of a bar, one being manœuvered at each end."

He also shows "a longitudinal section and plan of Pasqueau's double seated hurter and slide," which has rendered it possible to construct so wide a pass as that used at the Davis Island Dam.

M. Pasqueau says with reference to the limit of play of the tripping-bar: "The tripping-bar must travel about six inches to trip a wicket 4 ft. 11 in. wide, including clearance. It follows therefore that the projections should be spaced 4 ft. 11 in., minus 6 in., that is about 53 inches apart, so as to lower the wickets in succession, and that with a single tripping-bar it is impossible to lower more than nine wickets in succession, since the eleventh projection strikes the tenth wicket at the same time that the first projection strikes the first wicket. It is true that 16 wickets can be lowered with one bar, by separating the projections into nine groups, so as to lower the first four wickets in succession; the next six in groups of two, and the last six in groups of three, but this extreme limit has not been exceeded, and it even seems that it cannot be reached at all without danger, in case the wickets are very high. As 16 wickets of 4 ft. 11 in. make 78 ft. 9 in. linear, two tripping-rods working in opposite directions must necessarily be used to close a pass 157½ ft. wide, and it is not possible, with the system of lowering by tripping-bars, to make passes exceeding 160 feet without dividing them up by means of intermediate piers."

"In France the largest bars do not exceed 30 metres (98 ft.), and this length is considered an extreme limit which cannot be exceeded. To reach it, it is even now necessary to violently knock down five or six wickets at a time."

The Tripper-bar at Davis Island Dam.

The designs for the Davis Island Dam, as shown to the members of the American Society of Civil Engineers and of this Club on the annual excursion to Cleveland in 1879, provided for a navigable pass of 400 ft. to be opened by tripping-bars. This width was the least that could be adopted, as the channel spans of the bridges on the Ohio were required by law to be 400 ft., and the boatmen even then complained that they were too narrow.* Anything less than this span would have been a serious obstruction to commerce not to be tolerated. So it was proposed to use two trip-bars, each over 200 ft. long, against which foreign engineers earnestly protested as being impracticable, and, in view of the experience with bars 142 and 120 ft. long on the Kanawha, and with those of 98 ft. in length abroad, it will be seen that the objections were well grounded, and the idea was finally abandoned in favor of the Pasqueau hurter. In short, but for this hurter the experiment at Davis Island would doubtless have been a failure, as the dangers and delays incident to lowering the wickets by tripping each prop by hand (the only other method then known for long passes) would have been too serious to have been entertained.

Even with the present wide pass of 559 ft., all open, a coal fleet was wrecked one dark night by striking the pier, which is a source of danger to all boatmen. In November of 1879, when the river was partially closed by a cofferdam, the steamer "George Lysle" ran her "tow" aground at the dam and sunk three barges, and subsequently the steamer "Dexter" collided with the sunken barges and sunk three more barges, almost entirely blockading the channel way. The damages were estimated at from $10,000 to $15,000

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* The middle chute on the Ohio at the Falls, 300 ft. wide, is found by experience to be too narrow, and its width is now being increased to 500 ft.

Concerning the use of movable dams in France, M. Malézieux, Inspector General of *Ponts et Chaussées*, writes from Paris, April 4th, 1879:*

"Leaving out of consideration the ancient systems (prior to 1830), there only remain among modern dams three classic systems which one may recommend without rashness: the Poirée, Chanoine and Desfontaines system.

"The Chanoine system of *swinging wickets* was greatly improved, almost at the outset, by the substitution of a *foot-bridge on trestles*, for a *manœuvering boat.* Among the improvements in details, which have since been made, there is none more important than the suppression of the *tripping-bar.* M. Pasqueau has proposed to replace it by what he calls a *double-stepped hurter.*"

These hurters, with a traveling crane and other improvements, were put in at the dam known as La Mulatière at Lyons, where they are estimated to have effected a total saving in construction of 121,527.99 francs, or $24,305.60. Of this 55,371.63 was due to the hurter.

A pamphlet entitled "A New System of Movable Dams with Horses," recently published by S. Janicki, Director of the Moskva Navigation Company in Russia, was translated Sept. 24th, 1883, by Col. Merrill and submitted to the Chief of Engineers as a part of the literature of this subject. In this pamphlet the following tribute is paid to the invention of M. Pasqueau:

"In the latest application of the swinging wickets of M. Chanoine (at the La Mulatière dam at Lyons), Engineer Pasqueau, struck by the necessity of devising a new kind of movable dam which could be used for dams with high lifts and wide passes *without intermediate piers*, devised and applied an entirely novel arrangement, by which he could dispense with the tripper. Trippers, as is well known, are complicated pieces of mechanism, which practically limit the free opening between the piers of a dam to a maximum of about 50 metres (164 feet).

"The new arrangement of M. Pasqueau, which is very ingenious in its simplicity, consists in resting the props, which hold up the horses of the wickets, against a hurter and slide of a pe-

* R. C. of Eng., 1882, Part II, p. 1316.

culiar shape, which is fastened to the floor. This slide has two steps—the first supports the foot of the prop when the horse is upright; the other step is oblique and serves to push the prop sideways towards a horizontal groove, in which its foot can slide freely to the rear. . . . The double-stepped hurter of M. Pasqueau, against which rests the props of the wicket, permits the wicket to be raised, to be swung, and to be laid down, according to the necessities of the case, by a pull, which is always in one direction, and parallel to the thread of the stream. . . . The beautiful solution devised by Engineer Pasqueau for the La Mulatière dam, which is composed of Chanoine wickets with double-stepped hurters for props, and a service-bridge above for handling the wickets, has its justification in the local conditions due to the rapidity of the floods of the Rhone."

The accompanying illustration is taken from a photograph of one of these hurters as used at Davis Island. It is placed upon a dismantled wicket with its horse and prop, and tilted up so as to show the arrangement of the side flanges by their shadows.

This improvement may facetiously be called *a step in advance*, yet it is a vital step in the adaptation of the Chanoine system in this country, where the piers formerly required by the trip-bar system, with the dangers and delays incident to the use of such bars, would hazard the lives and property of those engaged in our river commerce and render it very expensive and unpopular, if not impracticable.

Manœuvering with Pasqueau Hurters.

As previously stated, the experience in manœuvering the dams at Nos. 4 and 5 on the Kanawha was very unsatisfactory, and as no reliable data are available for the comparison in this country, I quote from the report on the operation of the Pasqueau hurter at La Mulatière, as translated by Col. Merrill:

"From experiments made with wickets, the time for handling them should not exceed:

In lowering,	for one wicket,	3 minutes.
	" " trestle,	2 "
In raising,	" " wicket,	5 "
	" " trestle,	4 "

"That is, for a pass of 340 ft., containing 69 wickets and 34 trestles, worked by the same windlass: for lowering, 4 hours and 35 minutes, and for raising, 8 hours and 1 minute."

(These pass wickets are 14.3 x 4.6 ft.)

At Davis Island I was informed that at the trial of the dam, in manœuvering, three wickets were thrown in one minute and one wicket was raised in three minutes, which is much better time than that at La Mulatière. It is not possible, however, that this rate could be continued across the entire dam, and if we assume but one wicket per minute it would require about 7½ hours for one corps to lower the pass and three weirs with their service bridges. It was intended to operate this dam from a traveling crane striding the wickets, and for this purpose the tracks for the traveler were laid with the floor of the dam, and the piers were shortened at the rear ends for its passage, but the plan was abandoned and the service bridge as used at La Mulatière was introduced. One of the most important improvements in this bridge consists in modifications by which the number of trestles is reduced to one-half that formerly used, thus not only saving material and workmanship in the original plant, but reducing the depth of the trough in which the trestles were laid when down, preventing the silting up of this channel by covering the trestles with their attached iron flooring, and greatly facilitating the manœuvers by reducing the number, without increasing their length for a given height of pool, as well as opposing less resistance to drift or ice when they are up, which gave so much trouble on the Kanawha.

Concerning this SERVICE BRIDGE at La Mulatière, Col. Merrill gives the following translation of the French report of Engineer Pasqueau, dated (Lyons, 1879*): "Up to the present time the trestles have been made to equal the wickets in number, and the *depth of the trench* necessary to shelter them when down has rapidly increased with the height of the bridge. At La Mulatière for a bridge raised 20 ft. above the sill this arrangement would require trestles 23½ ft. high, lying six ranks deep and necessitating a trench 4 ft. in depth, which would have increased to in-

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* Page 1753, Report of Chief of Engineers, Part II, 1880.

tolerable proportions the danger of silting up and the difficulties of working. To avoid these inconveniences we have provided a *wide span service bridge*, placing the trestles 9.8 ft. apart and opposite the even numbered wickets. These trestles when down superpose in only three ranks, and thereby we have been enabled to reduce the depths of the trench to 28 in., to diminish the chance of silting up, to increase the rigidity of the trestle while at the same time diminishing the total weight of the bridge, and to reduce to 22.3 ft. the total height necessary in order to have the flooring 19.7 ft. above the sill." . . . (Then follows a description of the hinged flooring which saves time and labor in manœuvering, and serves as an apron for the trestles when laid in the trench.)

"In the ordinary trestle the upstream upright is vertical, and it is laid down lengthwise of a *vertical* chamber from 20 to 30 in. deep. When the dam is up gravel collects in this chamber and it is necessary . . . to remove the deposit by a diver every time the trestles have to be lowered. In our plan the trestles are symmetrical, their journal boxes are entirely in projection on the floor, and the latter is connected with the sill by a slope of one on two (one-half), which is less steep than the natural slope of sand deposits."

(These most important modifications of the Pasqueau system are shown in the last report of the Chief of Engineers, Part I, 1883, as having been adopted at Davis Island, where they have been successfully tried.)

The several features of this system may then be summed up as follows:

1. The water-way, or navigation pass, may be made of any length *without the use* of *intermediate* piers which are serious obstructions to navigation.

2. The dam may be built in sections of convenient lengths.

3. The complicated mechanism of the tripper-bar may be dispensed with and its cost be saved.

4. The wickets may be made much higher than when operated by trip-bars, and thus the number of dams in a continuous improvement be proportionately reduced.

5. The durability of the floor of the pass and of the wickets

themselves is greatly increased by preventing the shock caused by wickets 'tripped' under a considerable head of water; moreover, they may be made of metal instead of wood, and thus their life be extended greatly beyond the ordinary period of ten years.

6. Large dams may be worked rapidly, safely and surely, where if operated by trippers they would not be permissible.

7. The reduction of the number of trestles of the service bridge to one-half that formerly employed, resulting also in a reduction of their height, with corresponding economy in cost and weight.

8. A change of form of trestles rendering them more readily handled and less liable to 'silt' up when laid in the trough.

9. A change in the form of trough from a rectangle to an open trapezoid, thus producing an automatic scouring and facilitating the certainty and economy of operation.

10. The further precaution against silting by covering the trestles with their *attached* folding floor, thus also preventing the great loss of time required in the old style service bridge to carry the flooring to the ends of the dam and store it away.

It will readily appear from this summary that even with unlimited means at command, there are many places where any system lacking these advantages would prove an entire failure, and that this would most frequently happen where the necessity for some improvement in navigation was greatest, as on large rivers having an extensive inland commerce and subjected to sudden floods and long droughts, such as characterize the Ohio with its fluctuations of 60 ft. and over. In fact it was due to the existence of the peculiar requirements at La Mulatière, which necessitated a pass of 340 ft., that led M. Alfred Pasqueau after many attempts to solve the problem, involving much time and expense, to invent the present system, at once so simple, so effective, and so economical as to merit the award of the Legion of Honor from his government, and which has been so successfully introduced on our Western waters by the members of our United States Corps of Engineers under the supervision of Cols. Craighill and Merrill.

Cost and Benefits of this Improvement.

As the vital question in all innovations is, "Will it pay?" it

becomes necessary yet to consider the financial benefits resulting from the system of Chanoine-Pasqueau movable dams as adopted. Hence I do not intend to discuss their relative economy as compared with other systems, but merely their own costs and benefits.

The cost of the dam itself is as yet an uncertain quantity. In his Report to the Chief of Engineers, dated Sept. 1st, 1874, in discussing the subject, and when comparatively little was known, Col. Merrill had prepared plans for a lock 630 x 75 ft., with a lift of 6 ft., which he estimated to cost $200,000, and he adds: "The cost of movable dams will be

$344 per running ft. for the pass, and
227 " " " weir.

These estimates for the dams have been carefully prepared . . . by using the itemized bills of materials prepared from actual constructions in France, and are believed to be quite accurate. . . A movable dam of the average length of 1473 ft. will then cost as follows:

250 ft. of pass @ $344 per ft.	$ 86,000
1273 " weir @ 227 "	288,971
Total for one movable dam . .	$374,971
The cost of single lock with dam will be .	$574,971"

and for the 13 dams between Pittsburgh and Wheeling he makes the estimate $7,474,623.

These plans for a lock of only 75 ft. wide and pass of 250 ft. having been subsequently modified to remove the opposition of the boatmen, the estimates would be somewhat affected, though in widening the lock and reducing the total length of dam, there should be no very material difference in a work of this magnitude.

I have already shown that the appropriations for this work, including the estimate for this year, amount to $1,119,000, which is just about double the estimated cost of $574,971, made in 1874, and based upon French experience. Practical river men estimated the cost of each dam to be $1,000,000.

The Chamber of Commerce of Pittsburgh, in a pamphlet recently published,* refer to this work in these terms:

* The Mercantile, Manufacturing and Mining Interests of Pittsburgh, 1884.

"The completion of the Davis Island Dam, a work that has cost the United States Government nearly $800,000,* will give a pool of 7 ft. depth, of 1.62 sq. miles, sufficient to the harborage of over 12,000 steamboats and barges. . . . It is expected that harbor service boats for local towing will largely increase next season. The amount of hauling done from and between our mills is enormous, and a great economy of time and money can be effected by sending materials by river as soon as proper arrangements in the way of landings, etc., are made."

This $800,000, and the $110,000 estimated to finish, will bring the cost to nearly one million dollars, from which deduct, say $250,000, for lock and gates, and there remains for the movable dam of 1260 ft. and permanent dam, 456, total 1716 ft., a cost of $750,000, or $437 per lineal ft. That this would have cost even more but for the Pasqueau improvements is evident from the fact that all of them look to economy of construction, reduction of parts and simplicity.

The following estimate will show the direct saving to the Government, at the site of Davis Island, for a dam of 1260 ft.:

Detailed Estimate of Cost of Tripping-Bars and Machinery as Proposed for the Davis Island Dam (May 16th, 1879).

Total weight of tripping-bar, catches and counter-catches, hooks, splices, prisoners, guides and bolts, as estimated from drawings:—76,752 lbs.

Contract price for wrought iron, 6¼ cents . .	$4,797 00
Extra bolts and about 150 brass rollers, @ $4.50 .	700 00
Three sets of gearings for each of the *six* bars, with their housings, etc., @ $500	3,000 00
Labor in setting and aligning trip-bars and machinery—cutting wells, drains, etc. . .	4,000 00
By the substitution of the Pasqueau hurter there has been saved directly all the above-mentioned items, as well as the pier which would have been required had the bars been used.	
The pier, 11 x 17 x 35 = 243 yds., @ $10 . .	2,430 00

* Before completion.

The old form of hurter used with the trip-bar weighed with slide 800 lbs.; the Pasqueau hurters at David Island average 500 lbs., saving 300 lbs., @ $4\frac{1}{2}$ per lb. = \$$13\frac{50}{100}$ per hurter, which for the 332 = ...	4,476 00
By the use of the long span service bridge there were saved 153 trestles having an aggregate weight of 190,834 lbs., which, @ $6\frac{1}{2}$ cents, =	12,403 61
Labor required to set 153 trestles, and material and labor saved by reduction of depth of trench 1260 ft. long	4,000 00
Total amount saved at Davis Island by the use of M. Pasqueau's improvements	\$35,806 61

Which is equivalent to \$$28\frac{42}{100}$ per lineal ft.

The interest most benefited by the building of this dam are those of the boatmen in and around Pittsburgh. To form some idea of its pecuniary value to them, it will be sufficient to show the number of days of enforced idleness due to lack of water, and the value of the property thus affected.

In the reports of 1879 to the Chief of Engineers, Part II, page 1312, *et seq.*, Capt. Mahan summarized the observations on the discharges of the Ohio between 1855 and 1878 (24 years) in these words:

"The stages of the river are divided into three classes by those engaged in its navigation:

"1. The low-water navigation, or not less than 3 ft.

"2. The coal-barge stage, or not less than 6 ft.

"3. The coal-boat stage, or not less than 8 ft.

"The first is the lowest profitable stage for steamboats.

"During the 24 years ending December 31st, 1878, we find the following maxima, minima and averages:

Three foot navigation.	Average	duration of,		285	days.	
	Maximum	"	"	364	"	in 1855.
	Minimum	"	"	186	"	in 1871.
Six foot navigation.	Average	"	"	155	"	
	Maximum	"	"	212	"	in 1861.
	Minimum	"	"	69	"	in 1872.

Eight foot navigation.	Average	duration of,	89 days.	
	Maximum	" "	140 "	in 1864.
	Minimum	" "	25 "	in 1872."

Taking the average of these averages 285, 155 and 89, we have 176 days of navigation for vessels of average draft, and as the high water generally extends through the Winter season when navigation is interrupted by ice and other causes, the number of days available would be still further reduced. It will be within reasonable limits to put the average number of days interruption from ice per season at but 30, thus leaving 146 days available for navigation throughout the year, or 219 days of low water. This is just 60 per cent. of the entire year, during which time the capital invested in the boating interests is not only "tied up," but taxed by the necessary fixed charges to keep the property in repair and ready for use at the next "rise."

The value of this property, as given by the Report of the Pittsburgh Chamber of Commerce, is "4,323 vessels with a tonnage of 1,705,514 tons. Capital invested $9,740,0000."

If then this capital nets 6 per cent. per annum, when idle 60 per cent of the time, it would be worth very much more to make it available every day of the year; thus the interest of $9,740,000 @ 6% is $584,400, which represents the income for 146 days use of the capital invested in boats. If they could run the whole year, the additional revenue at this rate would be $876,600, which represents a capital of $14,610,000. This amount would be greatly augmented by the direct benefits to the coal interests in which there is a capital of $25,000,000 invested.

In his reply to the "Statements of the Coal and River Trade in Opposition to the Davis Island Dam," dated Feb. 26th, 1879, and addressed to Hon. Stanley Matthews, Col. Merrill says, with reference to the stages of water (page 3): "The fact is that a careful compilation of 22 years' guage operations at Pittsburgh shows that there is an average of 156 days, or five months, of 6 ft. navigation. But even this amount is dependent on rises, and it cannot be foreseen when these rises will come nor how long they will last. In 1871 there was less than 6 ft. in the channel at Pittsburgh from the 15th of May to the 15th of November, a

period of 6 months. During this time a steamboat, whose name I cannot recall, lay at the wharf at Pittsburgh, loaded, among other things, with agricultural implements. After some months of waiting, and much injury to her deck cargo by the action of the sun, she was unloaded, her freight was shipped by rail, and the boat sold by the sheriff. It is precisely this uncertainty of navigable water that makes an improvement so necessary."*

In fact, so thoroughly convinced are the boatmen of Pittsburgh of the value of the improvement, that one of them recently wrote that it was worth $1,000 per week to him to have the Davis Island Dam up. The river men, formerly its most bitter opponents, are now its most enthusiastic admirers.

"It has been estimated by Col. Long, that the western rivers afford a development of 16,674 miles of steamboat navigation, while the commerce of these rivers for the year 1843, . . . possessed a value of more than $220,000,000."†

In 1869 Col. W. Milnor Roberts caused to be compiled as accurate a statement of the value of Ohio River commerce as could be obtained, and he concluded that its annual value was $694,000,000;"‡ and again in 1874, in a report to the Government, Col. Roberts estimated "the river trade of each city, town and landing along the thousand miles between Pittsburgh and the mouth of the Ohio," at over $800,000,000. In other words, the river trade equaled the total foreign commerce of the United States, and political economists estimate home trade to be worth double that of equal amount with foreign countries.§

The greatest distance traveled by a Pittsburgh steamer was to Cow Island, on the Upper Missouri, a distance equal to 4,300 miles, which is as far as from New York to the Baltic or Mediterranean. At present more than 20,000 miles of inland navigation are open to the vessels of Pittsburgh in favorable seasons. A single steamboat has conveyed a tow of 20,000 tons of coal down

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* In 1856 there was less than 6 ft. from May 24th to December 4th, a period of $6\frac{1}{2}$ months. Since completion, Dam No. 4 on the Kanawha has been up 42 per cent., and No. 5 34 per cent. of the whole time, including the winter months.

† Ellet on the Mississippi and Ohio Rivers, pages 307 et seq.

‡ Reports Chief of Engineers.

§ Vide Report Pittsburgh Chamber of Commerce, p. 79.

the river. This is a cargo greater than any ever handled by the Great Eastern.

In his argument in favor of the improvement of the Ohio River, Major Ellet further says:

"The navigation of all streams bearing this vast and rapidly increasing commerce is interrupted during *more than one-third of the year*, by the want of water, or by ice, which accumulates to an injurious extent because of the want of water.* This interruption is equivalent in its effects to an annual tax upon the industry of the country equal to one-third the yearly expense of maintaining all the steamboats that are subject to the detention, together with the value of the delay upon all the property that is exposed and detained, and that of the deterioration and early destruction of all the boats that are compelled to run when there is too little water to float them safely. The number of boats navigating the western rivers is at this time (1848) not less than 1,000, and it is estimated . . . that the total loss from wrecks of steamboats on these waters for the year 1848 alone, amounted to $2,000,000."

In the Report for 1882,† Col. Merrill gives a tabular statement of losses due to bridge piers in the Ohio. "The table is as complete as it is practicable to make it, but there is good reason to believe that many cases of loss have escaped our search." . . . This table would be more valuable if it contained the number and position of the piers. It is headed: "*Revised List of Losses by Collision with Piers, etc., of Ohio River Bridges. Compiled June 30th*, 1882." (I quote only the totals.)

Beaver	*Bridge*, completed in 1878, losses to date, .	$ 28,587
Steubenville	" " " 1863, " " .	69,556
	(One wreck, Dec. 2d, 1869, of seven barges; loss, $17,638.)	
Bellaire	*Bridge*, completed in 1871, . . .	116,745
Parkersburg	" " " 1871, (and 4 lives lost),	55,000
Newport & Cin.	" " " 1872, . . .	34,625
Cinn. Southern	" " " 1877, . . .	9,812
Louisville	" " " 1871, . . .	70,600
Total,	. . . .	$384,925

* Gen. Weitzel in reporting on the canal around the Falls of the Ohio, says: "Canal in use only about one-half the time, in consequence of high water, ice and low water—(From June, 1874 to 1882, inclusive)

† Report Chief of Engineers, Part III, 1882, p. 1926.

"Some of these wrecks occurred during construction. I have therefore taken the average *annual* loss for each bridge, and find the aggregate of these losses to the boating interest on the river, between 1862 and 1882, to be very nearly $32,500. These are only the losses reported between Louisville and Pittsburgh. They represent a capital of $541,666, which it would therefore pay to expend annually to avoid them if possible."

Maj. Ellet continues: "There are no data for determining the loss consequent upon the detention of the boats; * but as the delay falls chiefly upon the largest steamers, which are always first arrested, the loss must greatly exceed the actual cost of maintaining and retaining 750 boats one-third of the year or 250 boats of average value the whole year, it will amount to not less than $3,000,000 per annum † over and above the loss now sustained on the property conveyed, and that on the commerce which cannot be conveyed.

By upholding the draft in the channel, the cost of transportation, which now fluctuates between 8 cents and $1.75 per hundred pounds, from Pittsburgh to Cincinnati, could be maintained, with profit to the carrier, at about the lowest present charge, and the whole business of the valley would experience a corresponding increase, consequent on the reduction of the cost of freight. A vastly increased tonnage would necessarily be conveyed at greatly reduced rates. The business of the transporter would become more certain and more stable. . . . . It is scarcely to be doubted that the maintenance of a depth of 5 ft., in the Ohio alone, at all seasons would save the country from an *annual* tax upon its present business of $5,000,000 or about eight times the sum necessary to produce the saving."

The total revenue collections in 1881 for the eight States which wholly or in part lie in the Ohio basin were $87,500,000, and the increase of the registered undertonnage ‡ of the Ohio alone from 1875 to 1881 has been 48½ per cent. § The total revenue collec-

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* Gen. Weitzel estimates the cost of delay to the Ohio River passenger steamboats at $200 per day, vide p. 1900, Report Chief of Engineers, 1882, Part II.

† This is $33 per day for each boat, or but one-sixth of Gen. Weitzel's estimate.

‡ About one-half the actual tonnage.

§ Gen. Weitzel to Chief of Engineers, 1882, Part II, p. 1899.

tions for the whole country were $135,000,000, of which nearly two-thirds were contributed by these States.

Thus it will be seen that the territory affected by the improvement of the Ohio is that tributary to 20,000 miles of inland navigation, having a commerce of greater value than the foreign commerce of the entire United States and producing, under the present comparatively unimproved condition of its river, two-thirds the revenue of the whole country. It is a well-recognized fact that cheap and certain transportation is one of the most important elements in promoting the welfare of the people, and developing the material resources of the country, and that there is no transportation that can compare in cheapness with that by water if it can be made reliable at all seasons.

By the Pasqueau-Chanoine system, as now used by the Government, all of these benefits may be secured to it, and the problem of the future navigation of our western rivers, with safety, certainty and despatch, may be considered satisfactorily solved.